ELECTRONIC PUBLIC PROCUREMENT OF CONSTRUCTION AND PUBLIC WORKS: TOWARDS A NEW REALITY

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Abstract
This paper will describe a new approach towards electronic public procurement of construction and public Works. The paper will analyse how the new Information and Communication Technologies (ICT) are changing the processes within the Building and Construction sector, namely the Building Information Modeling (BIM) approach combined with the Model-Driven Architecture, Service-Oriented Architecture and Cloud Computing. The combination of these technological approaches enable a full de-materialization of the whole building or public Works life-cycle and the possibility of public procurement become more efficient and increase market competitiveness.

Keywords – *Electronic Public Procurement, Building Information Modeling, Service-Oriented Architecture, Model-Driven Architecture, Cloud Computing*

1. INTRODUCTION

Procurement activities are quite intensive and occur in the different phases of any public building / engineering project. Public procurement can be of products or services highly structured, standard, and of routine nature. This type of public procurement is now addressed by existing electronic platforms, namely the public e-procurement systems and particularly public e-marketplaces (often run by private companies but commissioned by public governing bodies). These systems have proved to provide positive impacts and the range of benefits is diverse, from simple operational cost benefits to more strategic benefits like improvement of flexibility and responsiveness. However, compared with other purchases, procurement of public works / buildings / construction is characterized by high levels of unstructured goods and services, which makes the use of electronic systems for procurement activities more difficulty, particularly when much of the information that is necessary for the contractual arrangements are not well structured and in a “digital” processing format.

The Building Information Modeling (BIM) approach promise to introduce major change in visualization, coordination and planning processes of the building / engineering projects. However, the reviewing of the literature indicates that no efforts have been directed to the application of BIM for public e-procurement. Hence, this paper aims at providing a new conceptual approach for public e-procurement, through the use of the BIM approach and the convergence of recent technological architectures.

2. ELECTRONIC PROCUREMENT IN THE AEC SECTOR

2.1 STRUCTURED VS UNSTRUCTURED PROCUREMENT

The generic concept of “procurement” supports a delivery-relationship between buyers and sellers. Being a broader scope than “purchasing,” procurement involves strategic activities such as sourcing, negotiating with suppliers, and coordination with R&D [1]. There are two types of procurement on the two ends of a continuum: Structured and Unstructured [2]. “*Structured procurement*” processes are highly automated in terms of need identification, order, and fulfillment. The customized needs, high demand volume and potential uncertainties associated with supply can lead to high transaction costs for the buyer enterprise, if each transaction has to undergo the supplier search, approvals, processing and ordering. If the demand is regular and the product specifications do not change with time, organizations can reduce the transaction costs by negotiating a long-term contract with a supplier and designing an automated procurement process for reordering the items. Examples of such procurement include *tooling items, wirings, building materials, etc.*. “*Unstructured procurement”* occurs whenever there are products or services that are not suitable for any level of pre-defined automated procedures. Often organizations allow the end-users to take advantage of best deals available at the time of ordering and there is very little benefit of tying such procurement to product-specific purchasing steps with a particular supplier. These procurements tend to have very broad procurement rules giving plenty of freedom to the users to choose suppliers. Examples of this category of procurement include office equipment and furniture, trades subcontracting, customized building materials, etc.

The split between structured and unstructured procurement is particularly relevant in the procurement processes of public works/buildings/engineering. On every building / engineering product there are always the need for the purchasing of highly standardized and routine materials, equipment and goods and services, like e.g. building materials, hoisting equipment, concrete supply, etc., particularly during the construction / erection phase. However, much of the purchase activities relate with the procurement of highly unstructured supplies like specialist design activities, construction, specialist subcontracting services, or even one-off non-standardized construction products and equipments. Whilst the former activities are not significantly different from what happens in other industrial sectors, the later unstructured procurement activities, and their relevance on the whole construction life-cycle, provide a high degree of complexity, with a potential for relevant improvements brought by Internet-based systems, as later it shall be discussed. Obviously, this is regardless of the obligations mandated by the legal contractual requirements.

2.2. Electronic Procurement in the AEC Sector

In the AEC industry supply chain, procurement plays a significant role. However, the procurement term is usually referred to the contractual method and respective responsibility and risk sharing established between client/owner, designers and contractors. The main procurement methods can be [3]: Traditional Procurement; Design and Build; Public Private Partnerships (PPP); Management Contracting; and Construction Management. In public works context there are obvious implications in terms of responsibility related with the procurement of individual services, materials, equipment, etc. considering the different procurement methods, and also in how e-procurement can be applied. However, the functions and activities of e-procurement still hold regardless the responsibility.

Hence, the public works/construction procurement planning is a critical activity and is unique for each project. For an efficient procurement strategy, it is important for the contracting public agent to have the knowledge of suppliers who can meet different requirements and deliver the right services and products under given constraints. In early phases of the project, the procurement activities relate mainly which the invitation for tender for the project team (architect/designers) and eventually for consultants (e.g. project manager). These processes are rarely conducted electronically. Procurement activities become more intense in later stages, particularly with the procurement of contractors and with the procurement of material and product supplies, and subcontracting services. Indeed, an important activity on the procurement activity is searching for desired products over a wide range of available products from a large number of product suppliers. In large projects a large quantity of various kinds of construction material is required. For example a typical large scale public building like a hospital, an office building, a school, etc. have many rooms. Each room needs light fittings, a door, floor and ceiling, floor and ceiling coverings, furniture, power sockets, some form of ventilation such as windows, walls, wall coverings, etc. Multiplying the requirements by the number of rooms, that can range from dozens to hundreds, gives the scale of purchases needed for to buildings. These purchases can be made from a wide range of product suppliers. Today, many companies/product suppliers do their business via Internet-based systems, enable sharing of product information with contractors and potential buyers. Acquiring information from websites has become vital for contractors as more and more e-procurement websites are available on the Internet [4] [5]. By using an e-procurement system for construction materials, different kinds of information pertaining to materials, suppliers, manufacturers, buyers, agents, buying patters, buyer's reviews on products and services, etc. can be shared with its end-users. From the perspective of suppliers, e-procurement systems act as a mechanism for disseminating product information to a large number of potential buyers and contractors

E-procurement, however, has certain limitations. Construction materials generally have a large number of specification parameters. Entering the specifications into web-based forms of several e-commerce sites to find the best product is a time consuming task for a contractor. A contractor has to: acquire and maintain a list of several web addresses; interpret and understand the semantics and navigation methods used in different sites; be aware of new sites coming into the market; and do a manual evaluation of all the information acquired from different websites [5]. The aggregation of information through e-marketplaces may overcome some of these difficulties but does not eliminate them. Different e-maketplaces have their own material searching and display patterns and use different attributes for storing construction material data [5]. Moreover, there is heterogeneity in the management of similar types of information by different suppliers. Two product suppliers selling the same or similar products but storing it differently using different attributes make it difficult for a contractor to identify the similarities between the two. Construction material information systems are isolated with no interaction with each other [5]. Although Request for Quotations/Proposals may reduce part of the problem if the information product is highly structured, in general it is difficult for a contractor to find all the information using one system and even more difficult to do a comparison of the products supplied by different suppliers based on criteria such as product specification, cost, availability and delivery time. This becomes particularly relevant if they procure unstructured products and services, as they tend to be.

2.3. PUBLIC WORKS ELECTRONIC PROCUREMENT

Electronic procurement has known major developments in recent years in the public procurement context. Across the world public agencies are using e-procurement for reducing transactional costs and increase competition. There are differences of principle in the business issues between public and private procurement. Private procurement is geared to provide the best costs benefits balance. This is not always the case for public procurement where transparency and openness are paramount. However, large public e-procurement initiatives may have a clear goal to drastically cut costs. Public procurement is governed by legislation, which does not apply to private procurement. In both sectors, e-procurement is deployed to provide a better and more efficient service to the organization/community and to reduce costs.

Public Procurement in the European Union, is under the Directives 2004/18/EC and 2004/17/EC. Directive 2004/18/EC relates to the coordination of procedures for the award of public works contracts, public supply contracts and public service contracts. The directives leave to each country the settlement of the necessary legal procedures and the technologies to deploy national public procurement in general and e-procurement in particular.

In order to standardize e-procurement across national boundaries and across economical sectors (Construction, Oil & Gas, Transportation, Iron & Steel, Services) and Public Administration), it was set the CEN/ISSS Workshop on Electronic Procurement, that converged public and private e-procurement [6]. It was agreed the reference e-procurement process that captures the essence and specific phases of electronic procurement activity, namemly: e-Tendering, e-Awarding, e-Ordering, e-invoincing and e-Payment.

The eTendering process covers the preparation of an offer by a tenderer in response to a call for competition, as well as its submission to and receipt by the contracting authority. The eAwarding starts with the opening of received tenders by the contracting authority, and after a clarification step, ends with the contract being awarded to supplier. The eOrdering covers all activities from sending an order document from public buyer to supplier, up to the transmission of de-livery instructions for ordered goods or services. The eInvoicing process deals with claim for payment for goods or services that have been either ordered or delivered, received or consumed under the conditions agreed by supplier and public buyer. The ePayment deals with aspects related to payment, i.e. checking of invoices against existing documents on orders, and providing payment information on parties and financial institutions, e.g. banks.

The public sector in the EU should attempt to use existing eCatalogue standards for the creation and use of eCatalogues in public procurement, enabling suppliers to create “eCatalogue prospectuses” which can offer possibilities for re-utilisation. Such an approach should lead to a shared framework for eCatalogue prospectus creation, maintenance and transmission. The two most relevant initiatives/standards developed by international standardisation bodies in the area of eCatalogues are the UBL 2.0 and c-Catalogue, developed by OASIS and CEN/ISSS respectively [6]. Both standards primarily focus on post-awarding phases of procurement (eOrdering and eInvoicing), while their specifications can be also applied for pre-awarding, possibly following some extensions/customisations. These two prevailing initiatives/standards in the area of eCatalogue standardisation are compared in terms of their business documents, processes and messages, in order to identify similarities and gaps. There is currently an effort to working towards the convergence of these two standards. Apart from the need for standardizing processes and messages for conducting business electronically through the use of eCatalogues, the adoption of additional standards is necessary for standardizing the manner in which products and services are described in an eCatalogue. In order to overcome this problem, the path is either by the establishment of one, unique scheme that can accommodate the needs of all industries and all purposes, or by the establishment of a mapping/reference framework which can allow the interoperable co-existence of different schemes.

Besides the eCatalogues issues, e-procurement presents additional several technical challenges that create interoperability concerns regarding public procurement at European and global range, and that are being addressed by several R&D and industry initiatives. For example, European public tendering procedures require that companies submit certificates and attestations to proof that they comply with selection and exclusion criteria. Electronic business attestations that are interoperable are thus one of the major challenges to overcome, and that is being dealt at the PEPPOL project [7]. Electronic signatures interoperability is also a significant issue. Directive 1999/93/EC specifies the basic requirements for the use of electronic signatures, and in addition, there are technical standards available, such as X.509v3 for electronic certificates but in practice certification authorities do not recognize each other in all the cases, creating identification hurdles. Other less challenging issues are e-ordering and e-invoicing as these business documents are now standardized and XML-based.

The last e-Business Watch Report [8] addressing the Construction sector demonstrated that this sector lagged behind other nine economical sectors (e.g. telecommunications, food and beverage, manufacturing, ship building and repair, etc.) as far as e-procurement was concerned. Although the AEC sector can incorporate the recent developments on public and private e-procurement, most of the initiatives are focused on providing solutions for structured-based e-procurement approaches. As previously discussed, current building / construction projects, either private-owned or public works (building and engineering), mostly address unstructured procurement. This implies that e-procurement solutions must be able to both accommodate the described technical developments on public and private business context, but also develop ways to successfully cope with the challenges of procuring unstructured goods and services. The big challenge is implementing an approach for the building / construction whole life-cycle that provide more "structured" elements for procurement, namely by designing and developing the project around product models – necessarily structured – and easily sustain structured procurement. The Building Information Modeling (BIM) and the information standard IFC can be interesting solutions for dealing with the "unstructureness" of public building / construction projects and thus create the "information infrastructure" that easily supports public e-procurement.

3. THE BUILDING INFORMATION MODELLING APPROACH

3.1 THE BUILDING INFORMATION MODELING APPROACH

Building Information Modeling (BIM) allows the visualization, understanding, and construction to take place in the same 3D dimensions. BIM is promising to overcome current limitations of systems where communication takes place through 2D diagrams and text (drawings and specifications). BIM has also beneficiated with the advent of sophisticated CAD systems, where it was possible to enrich the 3D models of buildings and structures with, in addition to vectorial data, complementary data such as physical characteristics, unit costs, quantity take-offs, etc. Model intelligence refers to the fact that information may be contained in a virtual 3D model. Some of this information is physical, as it will contain information about the nature of an object, such as dimensions of the object, its location in relation to the location of the other objects in the model, the quantity of objects in the model, and other parametric information about the object.

For instance, considering the object “wall”, parametric information refers to the information that distinguishes one particular component from another, similar one. Indeed, walls have qualities in common, but each individual wall may have different characteristics, such as its dimensions, material (e.g. wood or concrete, etc.), or supplier information. Each aspect of this type of information can be programmed into the specific wall object so that it accurately represents what the project requires.

3.2 BIM and Interoperability

A number of the larger modeling software companies are now developing suites of modeling and construction-related software tools that are quite interoperable amongst them. However, most of the BIM applications of modeling and their complementary software tools only address interoperability among themselves and not in relation to other vendors’ applications.

The interoperability factor becomes even more acute if there is a goal of e-platforms to enhance the collaborative functions of BIM with traditional e-procurement, where building product objects (such as windows, doors, plumbing, etc.) besides parametric 3D model information must be coupled with transactional information, as in RFP, Order, Invoice, through e-marketplaces or through direct e-procurement. As previously discussed, universal e-procurement based on eCatalogues or in mechanisms that use product models must address the interoperability at the various levels. This imply the creation of data structures from the beginning of the building / engineering project that supports both the collaborative activities of the teams involved but also the e-procurement functions and activities in a seamless and automated way. As each building / engineering project tends to be unique, it is critical to the success of e-procurement that the BIM approach considers the use of universal interoperability standards for the various dimensions, i.e., not only on the e-tendering, e-ordering, e-invoicing or e-catalogues, but also on product and process models. This will require a demanding information architecture and management, based on state-of-art architectures like Model-Driven Architecture, Service Oriented Architecture or Cloud Computing.

3.3 BIM and Public Works E-Procurement

In some countries like Norway, USA, Singapore or Finland are changing the way public building / construction works are managed and how procurement processes are developed based on the BIM approach (see e.g. results of STAND-INN project, [9]). In Norway, three government organizations have been involved: the National

Office of Building Technology and Administration (BE); Statsbygg, the Directorate for Public Property and Construction Management – a property services agency; and the Norwegian Defence Estates Agency. BE is a joint initiative between the Ministry of Local Government, the construction industry and the public, and acts as a building control for the administration of building regulations. The Norwegian system for planning permission, Byggsøk, now uses an IFC BIM platform for, among other things, automated code checking. Statsbygg, meanwhile, uses IFC BIM as a tool to facilitate the flow of information through the entire value chain and whole life-cycle, from early design to construction, FM and end of life. From 2010, Statsbygg will require the use of IFC for new buildings. Finally, the Norwegian Defence Estates Agency is running pilots using IFC BIM.

In neighboring Finland, Senate Properties – the property services agency – carried out a number of pilots using BIM from 2001 to develop the use of product models. Based on its successful experience, Senate determined in October 2007 to require the use of IFC models in its projects and intends to embrace integrated model-based operations in the next few years.

Finland is also collaborating with public sector bodies in the US to develop BIM in public projects. The General Services Administration (GSA) in the US, which owns and maintains large portfolios of capital properties, set up the National 3D-4D-BIM Programme to promote the adoption of modeling and to lead pilot projects. The pilots have already shown the benefits of a BIM approach: the construction schedule is optimized (the duration of one pilot was reduced by 19%); design errors and omissions are uncovered at an early stage; communications with tenants and the public are enhanced; design and co-ordination are improved; and energy-conserving design decisions are facilitated. The GSA has commissioned the mandatory procedure of having design files of their files using IFC standard.

Early adopters in Norway, Finland and the US have used pilots to test the potential, and have been sufficiently impressed to go on to make IFC BIM a requirement. Still, as far as e-procurement is concerned, there have not been major advancements apart from the trend towards the making mandatory the submission of project files based on BIM approach and complying with standards like IFC or similar. However, this will not enable major developments as far as e-procurement is concerned, if BIM is not used to transform the whole process, and shifted towards the importance of the procurement functions and activities, as we shall propose later.

4. THE SOA4BIM FRAMEWORK FOR PUBLIC WORKS E-PROCUREMENT

4.1 EMERGING ARCHITECTURES FOR E-PROCUREMENT WITH BIM

The Model-Driven Architecture (MDA) comprises three main layers [10][11]. The Computation-Independent Model CIM) is the top layer and represents the most abstract model of the system, describing its domain. A CIM is a stakeholders-oriented representation of a system from the computation-independent viewpoint.

The middle layer is the Platform-Independent Model (PIM), and defines the conceptual model based on visual diagrams, use-case diagrams and metadata. For this it uses the standards UML (Unified Modeling Language), OCL (Object Constraint Language), XMI (XML Metadata Interchange), MOF (Meta Object Facility) and CWM (Common Warehouse Metamodel). The PIM defines an application protocol in its full scope of functionality, without platform dependencies and constraints. For an unambiguous and complete definition, the formal description of the PIM should concern using the correct business vocabulary, and choosing the proper use-cases and interface specifications.

The Platform-Specific Model (PSM) is the bottom layer of the MDA. It differs from the PIM as it targets a specific implementation platform. Therefore, the implementation method of the MDA, also known as Model-Driven Development (MDD), is achieved through a transformation that converts the PIM to the PSM. This procedure can be done through automatic code-generation for most of the system's backbone platforms, considering middleware-specific constraints, e.g. CORBA, .NET, J2EE, Web Services.

The World Wide Web Consortium (W3C) refers to the Service Oriented Architecture (SOA) as "a set of components which can be invoked, and whose interface descriptions can be published and discovered" [12]. Also, and according to Microsoft, the goal for SOA is a worldwide mesh of collaborating services that are published and available for invocation on a service bus [13].

SOA does not consider the services architecture from merely the technology perspective, but also proposes a normalized Service Oriented Environment (SOE) offering services' description, registration, publication, and search functionalities. Placing emphasis on interoperability, SOA combines the capacity to invoke remote objects and functions, i.e., the services, with standardized mechanisms for dynamic and universal service discovery and execution.

They can implement a business process by integrating services developed internally and externally to the company, providing a standard means of communication among different software applications running on a variety of heterogeneous platforms through the Internet. Web services are implemented in XML (eXtended Markup Language). The network services are described using the WSDL (Web Services Description Language), and the SOAP (Simple Object Access Protocol) is the communication protocol adopted. The registration of the services is in the UDDI registry (Universal Description, Discovery and Integration).

Although providing a significant contribution, the SOA alone is not yet the answer to achieve seamless interoperability between applications. For example, despite the efforts made to ensure compatibility between all the SOAP implementations, currently there is no single standard. The Web Services Interoperability Organization, WS-I, is a good example of an organization supporting Web services interoperability across platforms, operating systems and programming languages, and that has been developing efforts for the convergence and support of generic protocols for the interoperable exchange of messages between Web services [14].

Cloud Computing can be seen as an evolution over the traditional hosting and application service providers, though more aligned with the service-oriented environments, and less with client-server architectures. “Cloud computing”, or simply “Clouds”, has been defined by [15]: "*Clouds are a large pool of easily usable and accessible virtualized resources (such as hardware, development platforms and/or services). These resources can be dynamically reconfigured to adjust to a variable load (scale), allowing also for an optimum resource utilization. This pool of resources is typically exploited by a pay-per-use model in which guarantees are offered by the Infrastructure Provider by means of customized SLAs*."

The SOA in Clouds is used for addressing componentization, reusability extensibility, and flexibility. In order to construct scalable Cloud Computing platforms, there is a need to leverage SOA to build reusable components, standard-based interfaces, and extensible solution architectures. Within the Cloud Computing paradigm, there are some variations on what service is included. The most common reference is the Cloud Software as a Service (SaaS), which is the capability to use the provider’s applications running on a cloud infrastructure [15][16]. The applications are accessible from various client devices through a thin client interface such as a web browser (e.g., web-based email, Google Docs, etc.). There is no management of the underlying cloud infrastructure (network, servers, operating systems, storage, or even individual application capabilities), with the possible exception of limited user-specific application configuration settings [15][16].

Cloud Platform as a Service (PaaS) is the capability to deploy onto the cloud infrastructure of applications created or acquired by the user of the software services, though always using system tools supported by the provider [15][16]. There is no management or control over the underlying cloud infrastructure (network, servers, operating systems, or storage) but there is the possibility to control the deployed applications by the user, and possibly to host environment configurations [15][16].

Finally, Cloud Infrastructure as a Service (IaaS) is the capability to the user to provision processing, storage, networks, and other fundamental computing resources where there is the possibility to deploy and operate any software system, including operating systems and applications [15][16].

4.2 ELECTRONIC PROCUREMENT WITH THE SOA4BIM FRAMEWORK

Grounded on the latest architectures like MDA, SOA and Cloud Computing, and the developments in the construction sector with the Building Information Model (BIM) approach, a generic framework for the AEC sector was developed, as depicted in Figure 1 [17][18][22].

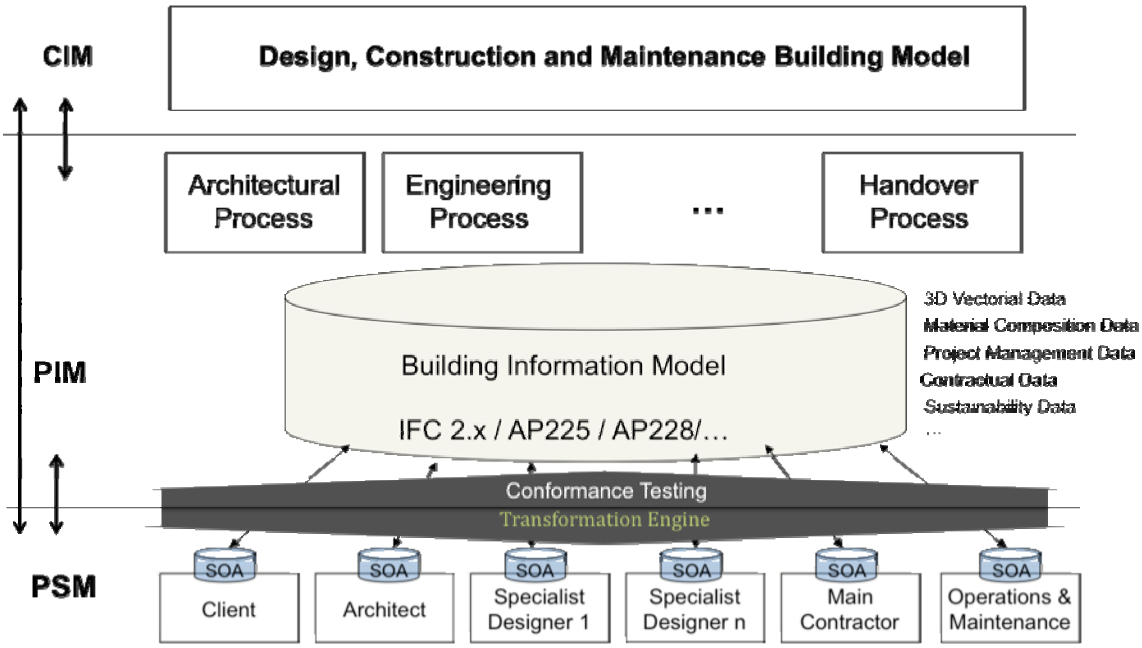

Figure 1 – Generic SOA4BIM Framework

The SOA4BIM Framework relies on the development of a Computational- Independent Model (CIM), that will model the design, construction, and maintenance building processes and products in a way that is not constrained by the requirements of the ICT platforms, i.e. only from a technical and business perspective. CIM can be grounded on some of the work previously developed, such as the Process Protocol Model [19], or on the work being developed more recently by the buildingSMART Initiative and its Information Delivery Manual (IDM), which is developing reference Process Maps for the whole construction process life-cycle [20]. Additionally, high-level e-procurement processes based on current developments of CEN/ISSS BI are also adapted and modelled at the CIM level.

Deriving from CIM, the SOA4BIM framework considers the design of the Platform-Independent Model, which will be a technology-neutral modelling of the various types of information in a construction project: 3D vectorial, material composition, project management (costs, time, etc.), contractual arrangements, sustainability, etc. In reality, the PIM layer is essentially a standard approach to BIM, where much of the work carried out by *de facto* and *de jure* standardization bodies may be considered, and standards like the IFCs, AP 225, AP 228, etc. should be used. For each project a PIM - BIM model is created with many of the data structures being reusable by the agents involved, since it uses neutral formats.

Although SOA4BIM Framework supports traditional client–server e-procurement model, it preferably adopts the Service Trading Model (STM) [6]. In this e-procurement approach the client (importer) only gets knowledge of available services at runtime by re-questing services and the fulfilling server (exporter) for an appropriate service from the trader at runtime.

This e-procurement system architecture relies on the SOA approach. The interactive generation of a tender document is that the client (importer) asks the user questions for the tender. After finishing this, the importer asks the trader to give him the name and address of an exporter which is able to generate a tender document in a specific format. The trader looks up the registered exporter services and gives back an appropriate exporter to the importer which opens a communication to the selected exporter. The exporter sends back the tender document to the importer and/or sends it to selected suppliers. SOA4BIM Framework enables moving beyond current traditional e-procurement systems and public e-procurement platforms that are portal-centric client/server model.

The integration of SOA with MDA will enable an engine for transformations and services that will automatically generate

Platform-Specific Models (PSM) such as Web-services, to each of the agents (client, architect, specialist designer, etc.). Hence, each time a service is evoked by any agent, there will be an appropriate automated transformation of the PIM to the specific PSM, through mapping. Conversely, whenever a construction agent requires the PIM-BIM model to be enriched with new information generated by their applications (e.g. Specifications or Bill of Quantities), new services would be made available, transforming the new PSM requirements into the enriched PIM-BIM model. Nevertheless, there must be a process of conformance testing in order to validate whether the enriched data conforms with initial PIM-BIM model, or requires an adaptation to the initial model.

4.3 Application Scenario in Project Conception and Design Phases

The SOA4BIM Framework is currently being implemented and validated in an industrial R&D project, designated by PLAGE [21], funded by the Portuguese Government, and by the companies Vortal, Primavera and Microfil. The project focus is on private and public e-procurement for the whole building and construction life-cycle, with both commercial and technical information being modelled in a cloud-based BIM server MDA and SOA architecture, using standards such as IFC and STEP APs, and with an e-procurement approach using SOA and Service Trading Architecture. A major concern of the project is to eliminate as much as possible unstructured information from public e-procurement processes. The project also seeks to follow current CEN/ISSS standards of e-tendering, e-awarding and e-ordering, along with e-signatures, although in a less critically way.

The PLAGE Platform is a platform system that combines three different platforms (Figure 2) [21]. Microsoft SharePoint 2007 is used as the business collaboration platform system and as the front-end and to implement a set of workflow and rule-based procedures for the e-procurement. The EDM Model Server˙ from Jotne EPM Technolgy is used for product and process BIM data management. Vortal eGOV is an e-procurement platform for the AEC sector for public and private eTendering, eAwarding and eOrdering. The disparate platforms work seamless in an integrated way through PSM instances, namely Web-services connections. These Web-services connections are also used to link to other AEC specialized software, like the Primavera Construction ERP Suite or Solibri Modeller. Apart from the later softwares, other specialized design and engineering applications export their IFC files to be used by the PLAGE Platform.

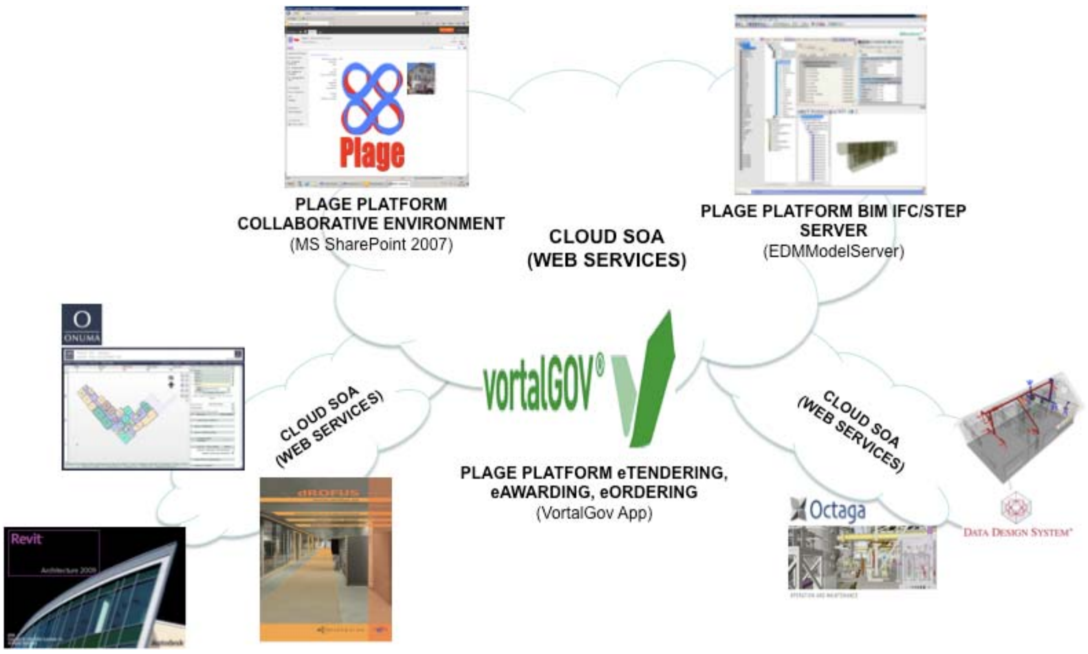

Figure 2 – PLAGE Platform Cloud Approach

Activities related with the concept design can be achieved without any e-procurement. In the detailed design phase, complex e-procurement interactions are likely to occur, with the involvement of disparate agents such as architects, structural engineers, electrical engineers, mechanical engineers, etc, for the specialities detailed design, and the high levels of unstructured procurement information that usually flows. The complexity increases also because competitive tendering is likely to occur, and there will be data flows – not only technical, but also commercial and managerial.

An application case has been developed for the design services of a building block for a public school. The client /owner triggers the eTendering stage through the PLAGE Platform workflow (functionality over the SharePoint application). SOA-based PSM, i.e. Web-services, will make the exportation of the BIM-IFC/STEP technical and contractual data from the EDM Model Server to the Vortal eGOV to launch the eTendering process. Besides the architectural designs and specifications, the PLAGE Platform does also release the tender documents according to the requirement of the BIM-IFC/STEP standards, and the templates for the bid reply of the competitors. In this process complementary information may be added like expected dates for execution, maximum price, selection criteria, etc. However, this information is incorporated on the tender documents through structured procedure with feeds also the original BIM IFC/STEP model. The Vortal eGOV will configure the eTendering and eAwarding procedures and selection process, and will export tender documents/files to the various building block competing designers using also specific PSM, since each designer may have in its own different application to import and work on the files.

After working on the technical building block designs and commercial data for the bid, the documents will then be exported by the designers through a similar mechanism to the Vortal eGOV. After the selection process has been conducted (on the Vortal eGOV platform), the acceptance of the BIM-IFC/STEP design bid, with technical and commercial data, is conditioned on the conformance testing performed in the PLAGE Platform. With the eAwarding of the selected designer, contractual arrangements are exchanged, maintaining the BIM-IFC/STEP web services approach. Once the off-line technical work is completed by the contracted designer, the BIM-IFC/STEP building block detailed design is exported to the PLAGE Platform, where, if conformant with the initial model, and accepted, will enrich the BIM model.

Although there was a major effort to have mainly structured information in the e-procurement process, the platform supports also some complementary unstructured information in the bid document. Hence the BIM-IFC/STEP building block detailed design and the filled bid template, exported to PLAGE Platform may contain additional information in the form of attached files (e.g. pdf format, JPEG, etc.) or eventually Web links. However each element of unstructured information has to be linked to an object within the BIM model. These complementary information and documentation may also be incorporated directly on the PLAGE Platform (rather than be imported along with the original file), through the manipulation of the BIM Model Viewer.

The PLAGE Platform architecture has providing successful results for the design phase of building and engineering projects, and its being validated with pilots conducted on projects of public buildings procurement in different design contexts.

5. CONCLUSION

Despite being a reality in many economical sectors, e-procurement still falls from reaching the tipping point in the AEC sector, and particularly in e-procurement for public works / construction / engineering and one of the main reasons lies in the inability to deal with the unstructured procurement, that is a substantial part of overall procurement activities. The emergence of the Building Information Modeling (BIM) approach, a reality in many construction projects, as been mainly focused on the technical aspects of project conception and execution, being an approach that has been addressing the increase of effectiveness in visualization, coordination and planning processes for public building projects in several countries like US, Singapore, Norway or Finland. It is argued in this paper that BIM can be a crucial approach for e-procurement for public works, through its capability of "mapping" traditional unstructured information into structured objects and data. The paper advocates the convergence of Model-Driven Architecture (MDA), the Service-Oriented Architecture (SOA) and the emerging paradigm of Cloud Computing into the SOA4BIM Framework. The application of the SOA4BIM Framework in the context of public e-procurement is being foreseen as able to overcome many technological barriers by re-using much of the standardization and research work done in the Electronic Public Procurement, BIM and in the AEC sector, namely the IFC and STEP standards, and at the same time use current technology, like Web-services, for implementation.

The application of the SOA4BIM framework in the public e-procurement context, in the conception and design phases of a school building project has been validated in the PLAGE platform application scenario, described in the paper. The main difficulties found are related with the ability to convert individual building objects in aggregate product and service "blocks" that are released to tender. The major problem is on the level of aggregation, as BIM objects tend to be very elementary and tenders focus on aggregate levels of products and services. Future work is envisaged to be the application of SOA4BIM framework on public building projects e-procurement on execution and maintenance phases.

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